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THE EFFECT OF NUTRIENT DEFICIENCY ON THE GROWTH OF LONGLEAF PINE SEEDLINGS

by

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This paper releases data gathered in current investigations at the Southern Forest Experiment Station, and is subject to correction or modification following further investigation.

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Longleaf pine (Pinus palustris Miller) in its natural range on the Gulf Coastal Plain often inhabits soils of low fertility. On such soils longleaf pine seedlings frequently grow poorly and show evidence of low vigor, but the specific cause for this poor growth, both under natural conditions and in the nursery, is often difficult to ascertain. A preliminary study was made, therefore, to determine whether it is possible to recognize seedling conditions or symptoms caused by the deficiency of specific mineral elements in the soil. If such symptoms can be recognized, nursery soils can then be specially treated to correct specific nutrient deficiencies.

Longleaf pine seedlings of low vigor often become infected with the brown-spot needle blight (Septoria acicola (Thüm.) Sacc.), which frequently causes almost complete defoliation. Siggers [1/] points out that the needle-blight disease is an important factor in the frequent retardation of growth of longleaf pine seedlings. Since susceptibility to this disease depends to a large extent on the vigor of the seedlings, a second object of this preliminary study was to determine the influence of various mineral nutrients on the vigor and general development of longleaf pine seedlings.

Method of Study

Fresh longleaf pine seeds of uniform weight (75 mg.) were germinated between moist paper towels. When the seedlings were three weeks old (i.e., in the cotyledon stage) they were placed in the top of 2-quart mason jars, over the mouths of which were placed pieces of paraffined kraft paper. The roots of the seedlings, which were inserted through holes in this paper, extended into the solution below. The cultures included (1) a four-salt full nutrient solution [2/] containing the essential elements nitrogen (N) as calcium nitrate ($Ca(NO_3)_2$) and potassium nitrate (KNO_3), potassium (K) as potassium nitrate (KNO_3) and potassium dihydrogen phosphate (KH_2PO_4), phosphorus (P) as KH_2PO_4, sulphur (S) as magnesium sulphate ($MgSO_4$), magnesium (Mg) as $MgSO_4$, calcium (Ca) as $Ca(NO_3)_2$, and iron (Fe) as ferric chloride ($FeCl_3$);

1/ Siggers, Paul V. The brown-spot needle blight of longleaf pine seedlings. Jour. Forestry 30: 579-593. 1932.

2/ The full nutrient solution contained:

Calcium	132 p.p.m.
Nitrogen	421 " " "
Potassium	141 " " "
Phosphorus	140 " " "
Magnesium	43 " " "
Sulphur	159 " " "
Iron	Trace

(2) a similar solution but lacking nitrogen; (3) a similar solution lacking potassium; (4) one lacking phosphorus; (5) one lacking magnesium; (6) one lacking sulphur; (7) one lacking calcium; and (8) one lacking iron. All these solutions were prepared with distilled water from a Barnstead "still." Six pine seedlings (in two jars containing three seedlings each) were grown in the greenhouse under normal light conditions and under each nutrient condition for 222 days. At the end of this period, the seedlings were removed from the jars, and the tops and roots of each were observed and measured; they were then dried to constant weight in an oven at a temperature of 45 to 50° C., and weighed.

Results

Data from this study are given in table 1. The results are discussed below, and the most characteristic symptoms in each case are underlined. Figure 1 shows typical seedlings from each nutrient solution and supplements the tabulated data and the discussion.

All minerals present: full nutrient solution

As might be expected, the seedlings growing in this solution had the greatest total dry weight, the most lateral roots, and the longest and the most needles. The taproots were considerably shorter than those of the seedlings growing in some of the other solutions, but all of the roots were sturdy, thick, and profusely branched. On a few roots some lenticels were in evidence, but these apparently did not reduce the vigor of either the roots or the tops. Mycorhiza were particularly evident on the roots of each of the seedlings in this solution. Most of the fascicles contained three needles. The seedlings showed a healthy green color and vigorous growth throughout the experiment.

Solution lacking phosphorus (-P)

The total dry weight of the seedlings was somewhat less than that of the seedlings in the full nutrient solution. The needles were not quite so long as those in the solutions lacking magnesium and calcium, but they were more numerous. The taproots were somewhat shorter than those in the solutions lacking potassium, magnesium, and calcium, but the lateral roots were more numerous. Externally, the absence of this element did not exhibit any evidence of injury. The seedlings possessed normal green color throughout the experiment. All survived and only those in the full nutrient solution were more vigorous. Also fewer fascicles had three needles in the solution lacking phosphorus than in the full nutrient solution.

Table 1.--Effect of nutrient deficiency on the development of longleaf pine seedlings. 1/

Nutrient solution	Average dry weight				Root		Fascicles (needles)		Survival	Vigor	Average pH of solution
	Root	Top	Total	Ratio top:root	Average length	Average number of laterals	Average length	Average number			
	---------- Gm. ----------				Cm.		Cm.		Percent	Class 2/	
Full	0.559	1.421	1.980	2.6:1	13.7	35	27.4	13	100	A	5.73
-P	0.466	1.050	1.516	2.3:1	20.3	25	19.6	10	100	B	6.14
-Ca	0.305	1.020	1.325	3.3:1	21.1	19	23.1	7	67	C	6.14
-S	0.290	0.816	1.106	2.8:1	16.3	15	21.3	7	100	B	6.21
-N	0.426	0.562	0.988	1.3:1	35.6	23	18.3	5	100	C	5.45
-Mg	0.147	0.647	0.794	4.4:1	24.1	14	21.1	7	83	D	6.06
-K	0.181	0.546	0.727	3.0:1	22.9	17	11.9	4	50	E	5.98
-Fe	0.117	0.396	0.513	3.4:1	13.2	10	16.8	4	83	D	6.28

1/ Arranged in order of decreasing dry weight.

2/ Explanation of vigor class:
A = very vigorous; 3 needles per fascicle; color, deep green.
B = vigorous; 2 and 3 needles per fascicle; color, green.
C = weak; 2 and 3 needles per fascicle; color, pale green.
D = weak; 2 and 3 needles per fascicle; color, yellow to pale green.
E = very weak; mainly primary needles; color, bluish green; very few fascicles.

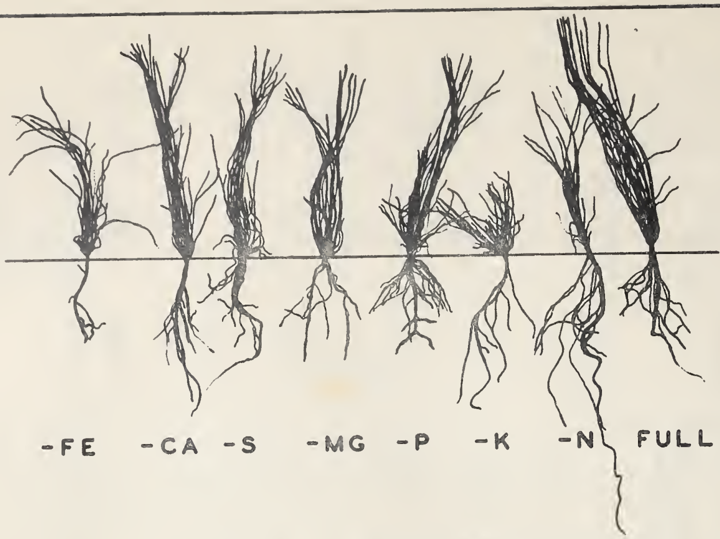

FIG. I : TYPICAL SEEDLINGS, SHOWING EFFECTS OF NUTRIENT DEFICIENCY.

Solution lacking calcium (-Ca)

During the first few weeks after establishment, the plants in this solution were very vigorous; the needles possessed a healthy green color and seemed to compare favorably with those growing in the full nutrient solution. Two months after establishment, however, growth apparently ceased, and an unhealthy pale color appeared in the needles followed by a reduction in the turgor, resulting in delicate, weak needles that had to be supported by a wire frame. At the end of 4 months, one of the six seedlings was dead and the rest were yellow-green and delicate. At the end of the experiment, two of the six seedlings were dead; the rest were yellow-green and spindly, and some needles were brown at the tips. The early, vigorous growth of the needles probably accounts for the relatively high weight of the tops. The weight of the roots, however, was low. In average length the needles ranked next to those in the full nutrient solution, but their number was only about half that of the seedlings in the full nutrient solution. The taproots were fairly long, and the number of lateral roots compared favorably with those in other solutions, but both taproots and lateral roots were delicate and densely covered with lenticels.

Solution lacking sulphur (-S)

These seedlings showed average dry weights somewhat lower than those growing in the solution lacking calcium. The needles averaged somewhat shorter than those of the seedlings lacking calcium, but were longer than all others except those of the seedlings in the full nutrient solution. The average number of fascicled needles was the same as in the solutions lacking magnesium and calcium. The taproots were shorter than those in most other solutions, but longer than those in the full nutrient solution and in the solution lacking iron. The number of roots was greater than in the solutions lacking magnesium and iron. All of the seedlings in the solutions lacking sulphur survived and showed no marked harmful deficiency effects. The needles were a healthy green, but they were also thin and spindly.

Solution lacking nitrogen (-N)

The seedlings began to show the effect of the absence of nitrogen two months after planting, and by the end of the experiment the needles were mostly pale green in the lower half and light brown from the middle to the tip. The lack of this element also expressed itself in the small number of needles; only those plants in the solutions lacking potassium and iron had fewer fascicles. All of the seedlings in this solution survived but they were delicate and sickly. The roots were long and covered with numerous lenticels, but were associated with few mycorhiza.

The amount of nitrogen necessary for the normal development of longleaf pine seedlings is apparently not very high. For several weeks after the experiment started it was difficult to detect any differences between the appearance of the seedlings growing in the full nutrient solution and that of the seedlings lacking nitrogen.

Solution lacking magnesium (-Mg)

The lack of magnesium was partially expressed in the very low dry weight of the roots. The needles were longer than those of plants in the solutions lacking potassium and nitrogen, but the tips of the needles turned brown early and the seedlings became pale green or yellowish and very weak or sickly. The taproots of the seedlings were long, but there were few lateral roots. Corkiness of the roots was not noticeable. One of the six seedlings died, and the survivors showed definite symptoms of weakness, expressed mainly in the color of the needles.

Solution lacking potassium (-K)

The seedlings showed a stunted, sickly condition from the very beginning and developed only a few, short, fascicled needles. At the end of the experiment these few fascicled needles were bluish-green except for their tips, which were dark brown or almost black. Most of the single needles were in the primary phase, bluish-green, short, and stout, but lacked brown tips. The needles were shorter and fewer than in any of the other solutions. Although three of the six seedlings died, and the survivors showed a very low vigor, the lack of potassium did not seriously affect the development of the taproot. The roots ranked third in length as compared with the roots in the other solutions, and the seedlings ranked fifth in number of lateral roots.

Solution lacking iron (-Fe)

The lack of iron began to have a visible effect within a month, and by the end of the experiment one of the six seedlings was dead and the rest were chlorotic and very weak. The surviving seedlings showed the lowest average dry weight recorded in the entire study. All of the surviving seedlings were pale yellow or almost white, weak, and spindly. The roots were decidedly corky, which was also true of the roots of the poor seedlings in the solution lacking potassium. Both the length of the taproot and the number of lateral roots were less in the solution lacking iron than in any other solution.

Summary and Conclusions

A preliminary study was made of the effects of the deficiency of seven essential mineral nutrients on the growth and development of longleaf pine seedlings. Knowledge of such effects is especially useful in a nursery, since correct diagnosis of soil-nutrient deficiencies must be made before the necessary remedial treatments can be applied.

The seedlings were three weeks old at the beginning of the experiment and were grown for 222 days in a four-salt full nutrient solution containing seven essential nutrients and in seven nutrient solutions lacking, respectively, nitrogen, phosphorus, potassium, sulphur, magnesium, calcium, or iron.

The absence of each of these elements produced definite symptoms. In the full nutrient solution most of the fascicles contained three needles, the foliage had a healthy green color, and the plants were vigorous. In the solution lacking phosphorus the needles also showed a healthy green color, but many of the fascicles contained only two needles. In the solution lacking calcium, the seedlings were pale green and spindly, and some needles were brown at the tips. In the solution lacking sulphur, the needles had a healthy green color but were thin and spindly. In the solution lacking nitrogen, the needles were pale green and delicate, and they were less numerous than in any other solutions except those lacking potassium and iron; many were brown from the tips down to the middle. In the solution lacking magnesium, the needles were pale green or yellowish and all had brown tips. In the solution lacking potassium, the few fascicled needles were bluish-green except at the tips, which were dark brown or almost black. Most of the single needles were in the primary phase, bluish-green, short and stout, but without the brown tips. In the solution lacking iron, the needles were pale yellow or almost white, weak, and spindly.

The poorest growth and the lowest dry weight occurred in the solutions lacking potassium and iron. The best growth and the greatest dry weight occurred in the full nutrient solution and in the solution lacking phosphorus. Mycorhiza were most numerous on the most vigorous seedlings.

A comparison of the vigor of the pine seedlings in the different solutions indicates that those which are supplied with all the essential mineral elements are the most vigorous and show the best growth and development. Although the seedlings growing in solutions lacking phosphorus and sulphur were not quite as vigorous as those in the full nutrient solution, apparently the natural requirement of the pine seedling for these salts is not very high, especially for phosphorus, for under natural conditions longleaf pine inhabits soils notably poor in phosphorus. Also the seedlings growing in solutions lacking nitrogen and calcium were somewhat less vigorous than the seedlings supplied with all the necessary elements, but here again it is evident that the requirement for calcium and nitrogen must not be very high, for these salts are not readily available in the soils inhabited by longleaf pines.

Especially poor vigor was shown by the seedlings growing in solutions lacking magnesium, iron, and potassium. These salts are evidently very essential to longleaf pine, and the natural soils inhabited by this species contain an abundance of iron and potassium; although the latter salt is not readily available to crop plants, it is apparently available to pines in

adequate quantities, for under field conditions potassium starvation seldom occurs. Furthermore, it is often noted that on freshly burned-over land longleaf pine seedlings appear especially green and vigorous after recovering their foliage. It is possible, judging from this study, that the ashes left on the surface of the soil may produce a temporary increase in salts normally not very available and thus stimulate the growth of the seedlings.